Pfizer Inc.
100 Route 206 North, MS 610
Peapack, NJ 07977
Tel: 908-901-8630

April 5, 2017

Ms. Khrystie Vázquez
Project Manager
United States Environmental Protection Agency
City View Plaza II Building, 7th Floor, Suite 7000
#48 Rd. 165 Km. 1.2
Guaynabo, Puerto Rico 00968-8069

**RE: SEMI-ANNUAL REPORT FOR PERIOD FROM JUNE 2016 TO FEBRUARY 2017
SVE CORRECTIVE MEASURES STUDY (CMS),
FORMER PFIZER PHARMACEUTICALS LLC,
ARECIBO, PUERTO RICO**

Dear Ms. Vázquez:

On behalf of Pfizer Pharmaceuticals LLC, please find attached a Semi-Annual progress report prepared by CH2M Hill Inc. - for the period from June 2016 to February 2017 for soil vapor extraction (SVE) RCRA corrective measures.

Please don't hesitate to call me if you have any questions regarding the attached report.

Sincerely,

William D. Sieske

Pfizer Pharmaceuticals LLC - a subsidiary of Pfizer Inc.

Cc: Adalberto Bosque, EPA (via email)
Rachel Griffiths, EPA (via email)

REPORT

Semi-Annual Report for Period from June 2016 through February 2017 - Soil Vapor Extraction System Startup, Evaluation, and Optimization Findings Former Pfizer Arecibo Puerto Rico Facility

Prepared for

Pfizer

April 5, 2017

CH2M HILL, Inc.
9191 South Jamaica Street
Englewood, CO 80112

Contents

Acronyms and Abbreviations

°F	degrees Fahrenheit
bgs	below the ground surface
CH2M	CH2M HILL Inc.
CMS	Corrective Measures Study
COC	contaminant of concern
EPA	United States Environmental Protection Agency
EQB	Puerto Rico Environmental Quality Board
ERTEC	Environmental Resource Technologies
eV	electron volt
lb/day	pounds per day
mg/kg	milligram per kilogram
OM&M	operation, maintenance, and monitoring
PID	photoionization detector
ppmv	parts per million by volume
ROVI	radius of vacuum influence
scfm	standard cubic feet per minute
SVE	soil vapor extraction
TCOC	total contaminant of concern
TM	technical memorandum
VGAC	vapor granulated activated carbon
VOC	volatile organic compound
wcg	water column gauge

Introduction

The purpose of this report is to summarize the findings of the startup, soil vapor extraction (SVE) system evaluation, and optimization review performed during the reporting period on the SVE system at the former Pfizer Arecibo, Puerto Rico facility. This report covers a reporting period from June 1, 2016 through February 13, 2017 in accordance with the *Final Corrective Measure Study Summary Report* (Environmental Resource Technologies [ERTEC], 2005), the U.S. Environmental Protection Agency (EPA) approval letter of pulsing/cycling procedures dated April 20, 2010, and the EPA letter dated April 7, 2011, which requests submittal of Semi-Annual Progress reports.

The SVE system was shut down from May 31, 2016 through November 21, 2016 to conduct soil investigations as described in a report by CH2M submitted to the EPA on January 5, 2017 (CH2M, 2017). Following the installation of additional SVE wells on November 22, 2016, functional and performance tests were initiated to obtain information for system operation, maintenance, and monitoring (OM&M) planning and optimization. This report specifically addresses the short-term SVE system optimization testing and initiation of the long-term SVE system testing. The objectives of this work were as follows:

- Evaluate the performance of the SVE blower by comparing it to manufacturer's data, assessing its condition, and value for projected future use
- Assess the alignment between the contaminant distribution and the different SVE well screens
- Estimate the relative radius of vacuum influence (ROVI)
- Prepare SVE mass removal calculations and determine the mass removal efficiency of each SVE well
- Evaluate (short-term) improvements to enhance mass removal
- Develop (longer-term) enhancements to improve the mass removal efficiency of the SVE system

Work performed in support of these objectives included review of pre-existing data and reports related to OM&M of the four existing SVE wells (SVE-1, VMW-1, VMW-2, and VMW-3C), review of data generated from startup of the two new SVE wells (SVE-2 and SVE-3) and one new vapor monitoring well (VMW-4), and onsite OM&M and equipment inspections and minor modifications. The following onsite activities were performed:

- Installed airflow rate monitoring ports on each SVE well to improve mass removal estimates from individual wells (23 November 2016)
- Conducted short-term startup testing of all six SVE wells to assess airflow capacity, vacuum, and ROVI (30 November through 1 December 2016)
- Repaired the vacuum relief valve and closed the dilution (air bleed) valve to increase vacuum on SVE wells and increase mass removal rates (13 December 2016)
- Performed approximately 2 months of routine OM&M of two new SVE wells, SVE-2 and SVE-3 (2 December 2016 through 13 February 2017)

The primary equipment used for the SVE system includes (see Figure 1):

- 20-gallon fiberglass moisture separator
- Ametek (Saugerties, New York) Rotron EN6F72L regenerative blower – 5 horsepower (hp), 3 Phase, 60 Hertz (Hz), 100 standard cubic feet per minute (scfm) at 58 inches water column gauge (wcg) vacuum

- Appurtenances including an inlet air filter, inline differential pressure gauge to estimate airflow rate, adjustable vacuum relief valve, and discharge air temperature gauge
- CARBTROL (Bridgeport, Connecticut) G2S drums (two in series) – 170 pounds each, virgin coconut shell vapor granulated activated carbon (VGAC), 300 scfm capacity

The SVE well network includes SVE-1, SVE-2, and SVE-3 and vapor monitoring wells VMW-1, VMW-2, VMW-3C, and VMW-4. Following the soil investigations to determine the areas of highest concentrations of contaminants, SVE wells SVE-2 and SVE-3 were installed with screened intervals of 100 to 105 feet below the ground surface (bgs) and 195 to 200 feet bgs, respectively. They were installed adjacent to each other at a location approximately 20 feet northwest of the cluster of vapor monitoring points consisting of wells VMW-1, VMW-2, and VMW-3C (CH2M, 2017). Similarly, vapor monitoring well VMW-4 was installed with a screened interval of 95 to 105 feet bgs at a location northwest of vapor monitoring well VMW-1 at a distance of approximately 10 feet. Figure 2 summarizes the soil borings installed during the August to October 2016 investigation and the depths of screened intervals for previously and newly installed SVE and vapor monitoring wells relative to the SVE system location.

The following sections provide a summary of the findings and the planned improvements and enhancements.

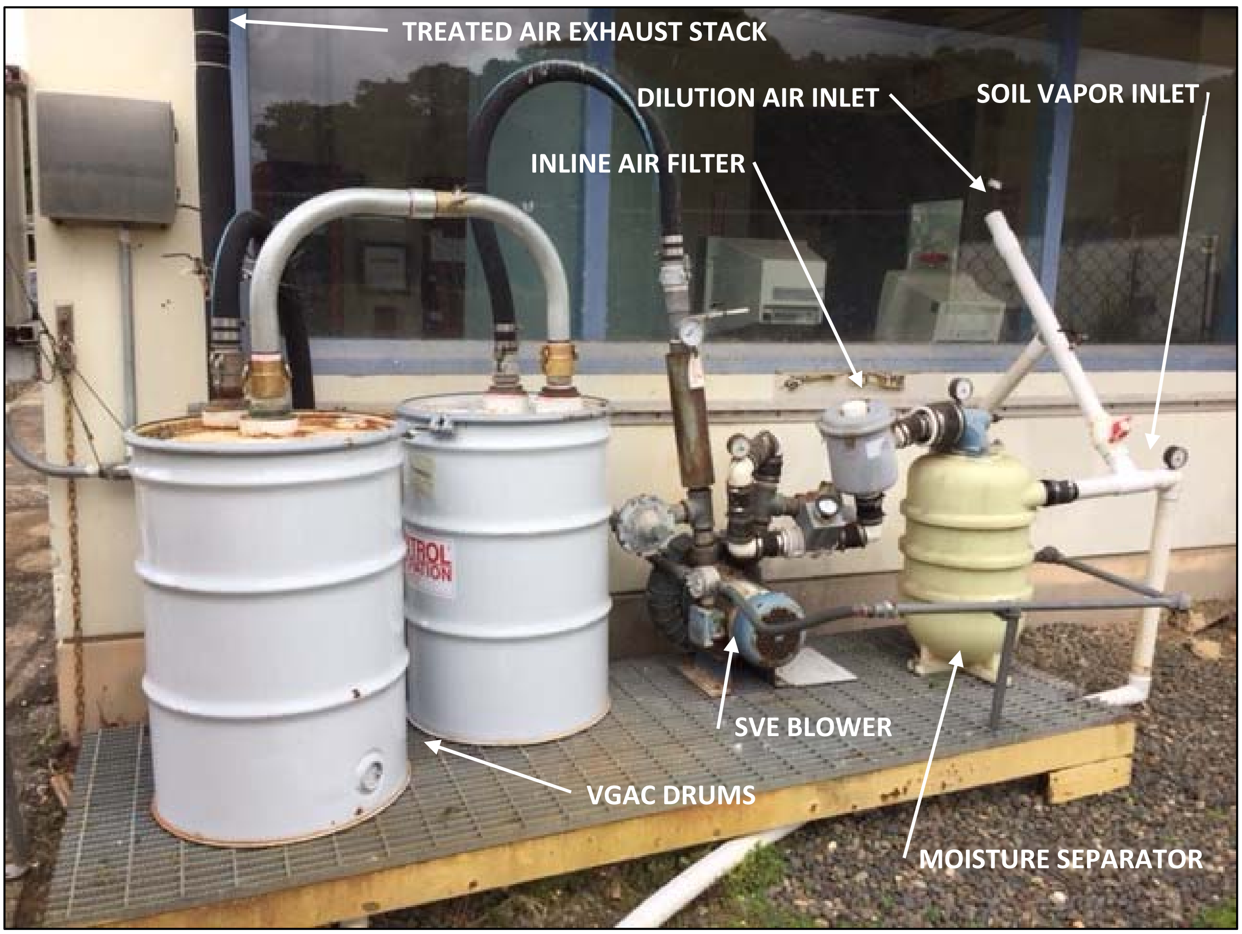


Figure 1. Soil Vapor Extraction System

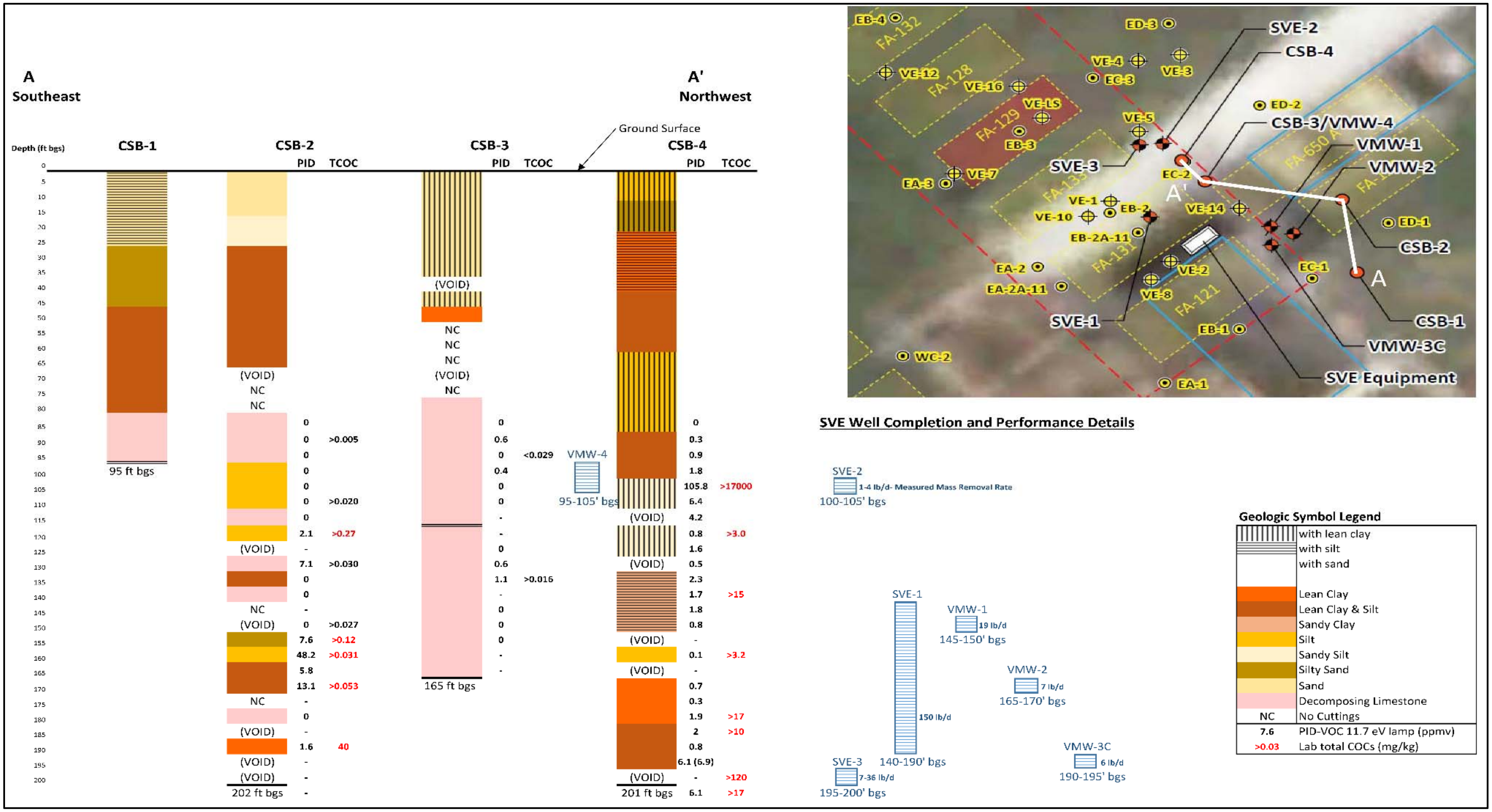


Figure 2. Summary of Geology, Contaminant Distribution, SVE Well Installation, and SVE Well Performance

SECTION 1

Contaminant Distribution

Figure 2 summarizes the findings of the soil boring investigation, geology, field headspace photoionization detector (PID) results, and lab concentrations of total contaminants of concern (TCOCs). TCOCs include acetone, carbon tetrachloride, chloroform, and methylene chloride. Figure 2 is to scale in the vertical, but not the horizontal. In red font are TCOC concentrations greater than 0.03 milligram per kilogram (mg/kg) in soil. Field PID measurements using an 11.7 electron volt (eV) lamp generally did not correlate well to the TCOC lab results. Geology was highly heterogeneous with alternating sequences of decomposing limestone, low permeability silt/clay, and voids. CSB-4 contained no limestone and appears to be wholly located within karst solution feature or trough, as described in the Corrective Measures Study (CMS; ERTEC, 2005). The largest TCOC concentrations were found in soil boring CSB-4, closest to the release location at underground storage tank (UST) location FA-129 shown in red on the site plan inset on Figure 2. Elevated TCOC concentrations were detected throughout the 100- to 200-foot bgs depth interval, but were highest (i.e., >100 mg/kg) at depths of 100 to 105 and 195 to 200 feet bgs. The upper impacted zone is a depth containing sandy silt with lean clay and the deeper consisted of lean clay and silt underlain by a void.

Because the pre-existing SVE wells were not screened across the two most impacted depth intervals identified by recent sampling, two new SVE wells were installed and screened across these zones. The SVE well screen intervals for the four pre-existing (SVE-1, VMW-1, VMW-2, and VMW-3C) and two new SVE wells (SVE-2 and SVE-3) are shown on Figure 2. The new SVE well layout is shown on the inset site plan. The new SVE well screen arrangement is better aligned with the depth intervals of highest remaining soil impacts.

Soil Vapor Extraction System Effectiveness Evaluation

2.1 Soil Vapor Extraction Blower Performance Assessment

Beginning in late November 2016, CH2M conducted initial system performance tests beginning with the evaluation of the SVE blower and individual SVE wells. Functional tests began with the SVE blower, air/water separator, dilution (bleed) air valve, vacuum relief valve, and SVE blower off-gas VGAC filtration vessels and were operated according to the pre-existing conditions as set by the operation staff at ERTEC (Rio Piedras, Puerto Rico).

Between 22 and 29 November 2016, the SVE blower was operated with the inlet open to the atmosphere at various vacuum levels not to exceed approximately 55 inches wcg to avoid system overheating issues. Accordingly, the vacuum relief valve had been adjusted to open between 55 and 60 inches wcg vacuum. As shown on Figure 3 and listed in Table 1, the flow versus vacuum results from the initial blower tests typically followed the lower to middle range of the manufacturer's blower performance curve. For example, the manufacturer predicts approximately 130 and 170 scfm at a vacuum of 60 and 30 inches wcg, respectively. The manufacturer's specifications sheet for the SVE blower is included in Attachment 1.

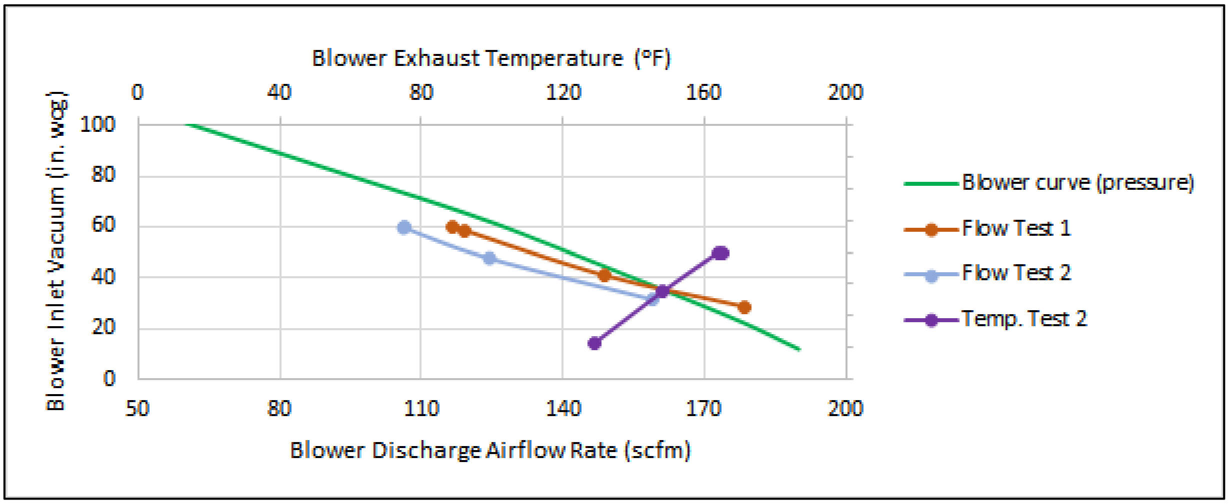


Figure 3. SVE Blower Performance Evaluation (November 2016)

On 13 December 2016, following inspection of the blower impeller vanes and motor efficiency, and making adjustments to the vacuum relief valve, further evaluation of system performance led to the determination that the low-end blower operation was related to the concern of blower discharge overheating and degradation of VGAC treatment performance. As presented in the manufacturer's specifications (and on Figure 3) when operating the blower at its high-end vacuum, discharge air temperature can increase as much as 80 degrees Fahrenheit (°F) above ambient. At temperatures greater than 140 °F, for example, VGAC performance may degrade. The effects of temperature on volatile organic compound (VOC) adsorption is described in Activated Carbon Adsorption for Treatment of VOC Emissions (CARBTROL Corporation, 2001) and is attached for reference as Attachment 2. CARBTROL is the current supplier of activated carbon to the Arecibo facility.

Following adjustments to the vacuum relief valve to allow higher vacuum operation, CH2M was able to verify proper operation of the SVE blower across the manufacturer's full range of vacuum and airflow and confirm the SVE blower is in good working condition. Following that confirmation, the vacuum relief valve was reset to allow operation to a maximum temperature of approximately 160 °F. A higher temperature was allowed for this interim SVE operation because TCOC emissions were consistently well below the Puerto Rico Environmental Quality Board (EQB) Regulation for the Control of Atmospheric Pollution (July 1995) exemption threshold of 15 pounds per day (lb/day) of VOCs. As long as emissions are below the EQB threshold, the SVE system can be operated at the higher vacuum and achieve more effective mass removal from the subsurface. As discussed in detail in Section 3, a heat exchanger will be installed for long-term, higher vacuum operation.

2.2 Soil Vapor Extraction Zone of Influence

SVE zone of influence testing was initiated following functional testing of the SVE system on 30 November 2016. Individual SVE wells were brought online to assess airflow rates and measurable pressure distribution between the SVE wells and vapor monitoring points. ROVI testing was conducted by individually applying approximately 30 inches wcg vacuum to the wellheads and measuring the resulting wellhead vacuum observed at the surrounding wells over approximately 30-minute intervals. For example, vacuum was applied using the SVE blower at SVE-1, while the remaining wells (i.e., SVE-2, SVE-3, VMW-1, VMW-2, VMW-3C, and VMW-4) were closed between the SVE blower and the wellhead, leaving the wells only open to the subsurface soils based on their corresponding screened intervals.

Results of the ROVI testing indicated vacuum influence primarily in the upward vertical direction, based on gradients observed in subsurface pressure between neighboring wells. No pressure differentials were measured between wells laterally nor in the downward vertical directions. For example, when vacuum was applied at deeper depths in wells SVE-1, SVE-3, VMW-1, VMW-2, and VMW-3C, measurable pressure differential was always observed at well SVE-2. However, when inducing vacuum at well SVE-2, no pressure differential was measured at wells SVE-1, SVE-3, VMW-1, VMW-2, and VMW-3C. Likewise, no vacuum was observed in adjacent wells screened at the same depth (e.g., SVE-1 and VMW-1, VMW-2, or VMW-3C) when either was operating.

On 2 December 2016, the SVE blower vacuum was increased to approximately 40 to 50 inches wcg and applied to wells SVE-2 and SVE-3. Results of this test indicated that with the increased vacuum and connection between the wells became more apparent. Because of the offset vertical spacing between the well screen intervals and the presence of varying layers of clay, silt, and voids, as shown on Figure 2, vacuum influence is difficult to ascertain or generalize. It spans laterally and vertically, following zones of higher permeability (i.e., interconnected voids). The effective ROVI (accounting for both vertical and horizontal directions) was estimated by plotting angular distances between well screen intervals against wellhead vacuum data collected on 2 December 2016 with SVE-2 and SVE-3 operating at vacuums of 40 to 50 inches wcg. The results of this analysis are shown on Figure 4, which indicates an estimated ROVI of up to roughly 30 feet at a subsurface vacuum of 1 inches wcg. This estimated ROVI is greater than the ROVI reported in the CMS of approximately 19 feet; however, vacuum influence varies greatly depending on the operating conditions and where vacuum is measured, as previously discussed. Of note, on 3 January 2017, during operation of both SVE-2 and SVE-3 at 61 inches wcg, a small vacuum was observed in all wells except SVE-1. This is another line of evidence that the SVE system is effectively extracting vapors from throughout the zone of affected soils. A summary of the vacuum data used in the assessment is included in Table 2.

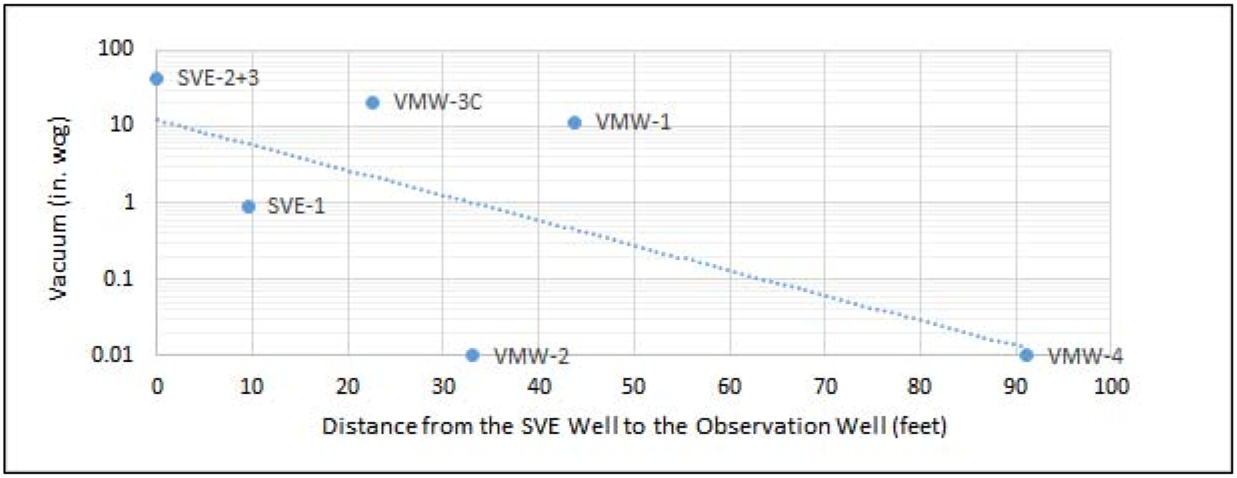


Figure 4. SVE Radius of Vacuum Influence (vacuum applied to SVE-2 and SVE-3 on December 2, 2016)

2.3 Mass Removal Estimates

Since startup of the SVE system for performance testing and equipment evaluations, soil vapor concentrations were monitored at least weekly at the operating SVE wells and the SVE blower inlet and discharge stack using an 11.7 eV PID[1] . Because the PID is useful only as a screening tool and typically cannot be used to quantify actual contaminant of concern (COC) concentrations, soil vapor samples were also collected five times (weekly for the first two weeks and monthly thereafter) using Summa canisters and sent to TestAmerica Laboratories, Inc. (Burlington, Vermont) for analysis of VOCs by U.S. EPA Method TO-15. TO-15 results were reported for COCs including acetone, carbon tetrachloride, chloroform, and methylene chloride. The sum of the COCs is herein reported as TCOCs. A listing of PID and laboratory analytical results are listed in Table 3.

An attempt to correlate the field PID measurements and the Summa sample results was made using data from the operating SVE wellheads and the SVE blower inlet, which represents a combined soil vapor quality from all SVE wells and dilution air. The correlation was made by first converting the field PID values collected in units of parts per million by volume (ppmv) to an equivalent mass unit basis using the ideal gas law with the assumptions that the soil vapor is in equilibrium with standard atmospheric conditions. The resulting equivalent mass unit was then plotted against actual laboratory results for Summa samples collected on the same day as the PID readings. A summary of the correlation between the PID readings and the laboratory values, including the average mass of TCOCs removed per day per SVE well are included in Table 3. Review of Figure 5 illustrates the linear correlation (best fit, setting zero X,Y intercept) between the PID readings and the laboratory values. The correlation is poor (R^2 = 0.62); therefore, use of the correlation equation should be revised as new data are collected and results used only for order-of-magnitude estimate purposes.

[1] It should be noted that it appears that historical PID measurements were performed using a 10.2 eV PID lamp. Detection of carbon tetrachloride requires an 11.7 eV lamp. Therefore, all prior PID measurements should be used with caution.

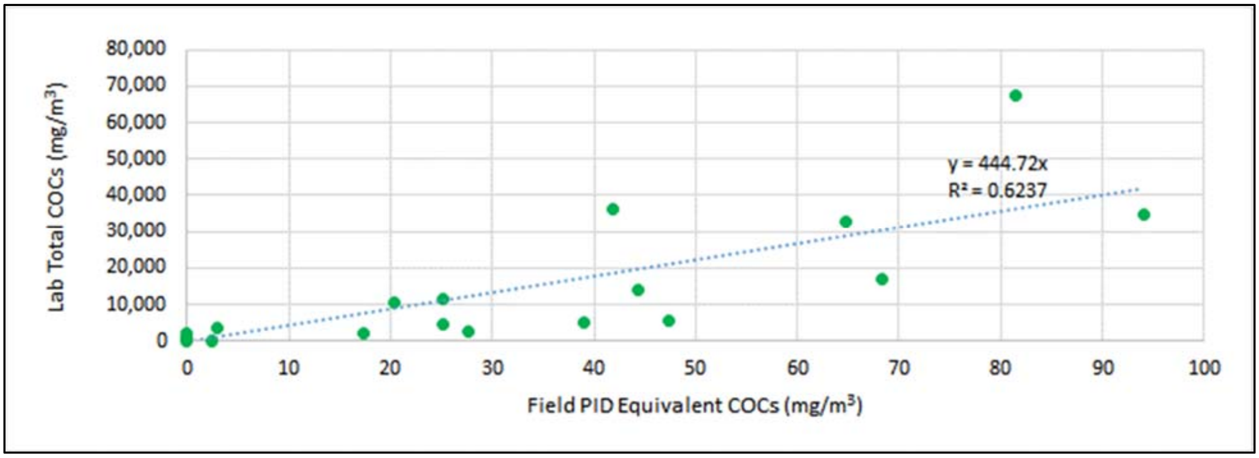


Figure 5. Correlation of PID Readings to Laboratory TCOC Results

Figure 6 shows the results of the cumulative mass removal estimates for SVE-2 and SVE-3. It is estimated that approximately 2,600 pounds of TCOCs were recovered from wells SVE-2 and SVE-3 between 2 December 2016 and 13 February 2017, at average rates of approximately 17 and 18 lb/day, respectively.

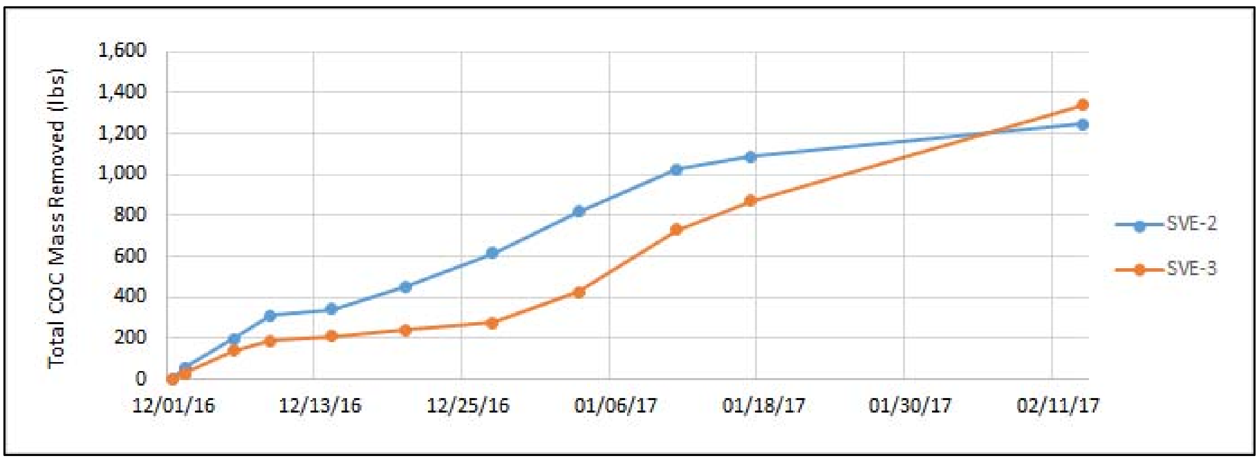


Figure 6. Cumulative Mass Removal for SVE-2 and SVE-3

Review of the *SVE Pulsing Operations Progress Report No. 11* (ERTEC, 2015) indicated that TCOC removal rates from wells VMW-1, VMW-2, and VMW-3C did not exceed 0.8 lb/day per well under normal operating conditions, which consisted of wellhead vacuums and flowrates averaging 13 inches wcg and approximately 15 scfm, respectively, from 1 April 2016 to 31 May 2016. Soil vapor Summa samples were collected from each operable SVE wellhead, during operation of the SVE system, on 1 April, 2 May, and 31 May 2016 and multiplied by the average airflow rates to yield estimated mass removal for each month. In total, approximately 80 pounds of TCOCs were recovered during the 60-day period of performance from 1 April through 31 May 2016. The current SVE system operation using the new SVE wells is greater than 10 times more effective at mass removal.

Some VGAC breakthrough at the downstream dual-series vessel was detected after approximately 60 days, as indicated by the rising effluent field PID readings and lab data that indicated similar influent and effluent TCOC concentrations on 13 February 2017. The maximum calculated atmospheric emission was approximately 1.2 lb/day, well below the Puerto Rico EQB threshold for permit exemption. Both VGAC vessels were replaced with equal CARBTROL G2S units on 22 February 2017.

Soil Vapor Extraction System Enhancements

3.1 Mechanical Improvements

The following modifications to the mechanical components of the SVE system are being evaluated to improve mass removal of the SVE system:

- As discussed in Section 2.1, the temperature of the SVE blower discharge air increases proportionally to blower inlet vacuum and, as a result, the discharge air temperature can exceed the manufacturer's recommended temperature for efficient adsorption of VOCs on the VGAC. This can be remedied by installing an air-to-air heat exchanger on the SVE blower discharge upstream of the VGAC filters. The blower exhaust can be cooled from temperatures of up to 100 °F above ambient to a temperature within the manufacturer's allowable range for efficient VGAC adsorption. For example, a blower discharge temperature of 180 °F at a flowrate of 70 scfm may be cooled to approximately 110 °F when using a heat exchanger capable of moving 250 scfm of cooling air at 100 °F. The heat exchanger design can be tailored to output a temperature range that is most suitable and efficient for VGAC sorption of the site-specific VOCs using manufacturer's isotherms.
- The use of VGAC vessels constructed with full bottom plenums will replace the current central radial flow design vessels. Radial flow vessels consist of two vertically screened pipes positioned in the center of the vessel, thereby short circuiting some of the airflow. Vessels constructed with a vessel-wide plenum across the bottom of the drum ensure complete contact across the full width of the carbon bed as the air travels vertically from bottom to top. As a result, plenum-style vessels allow for better contact and more complete carbon usage.
- Modifications to the SVE system piping and layout may increase the blower efficiency and improve air velocity measurements at the blower. Modifications being evaluated include: 1) relocation of the SVE blower relative to the system platform to allow for straighter pipe runs, and 2) installation of pipe stands to reduce 90° elbows; and 3) installation of a permanently mounted pitot tube (more accurate than an anemometer). Additionally, the replacement of ball valves with plug valves will allow the user to fine tune the amount of dilution air allowed into the system and, when coupled with an inlet filter/silencer, it should create less turbulent flow as it is combined with the wellhead flow.

3.2 Operational Improvements

The following operational changes are planned to improve the mass removal rate of the SVE system:

- Maximize ROVI and mass removal from the SVE wells by maximizing the vacuum at the SVE blower inlet. As specified by the manufacturer, the SVE blower is capable of maintaining an inlet vacuum of approximately 80 inches wcg, while producing approximately 50 scfm of suction airflow. The maximum SVE blower inlet vacuum cannot be maintained without creating excessive temperatures; therefore, some dilution air is necessary to maintain temperatures that comply with manufacture specifications. In order to try and maximize vacuum and ROVI, a heat exchanger will be installed (as stated in Section 3.1). With the heat exchanger is installed and tested, it may be feasible to operate all SVE wells concurrently without air dilution and obtain enough airflow to keep the discharge cool.
- As has been performed in the past, pulsed or cycled operation of select SVE wells will continue to maximize TCOC mass recovery rates. Soil vapor concentrations from the older SVE wells (SVE-1, VWM-1, VWM-2, and VWM-3C) may decrease more quickly than the newer wells, because they

have been operated for a long time and more limited recoverable mass may be available from them. As a result, their ON times may be shorter and OFF times may be longer to allow soil vapor re-equilibration prior to restart. In the new SVE wells (SVE-2 and SVE-3), as the mass is removed from the soil pores at rates greater than volatilization of the COC mass in the soil, SVE mass recovery rates will continue to decrease. If all SVE wells cannot be operated at once because of SVE system restrictions, the SVE wells can be operated in zones to allow non-active zones to re-equilibrate. As the operating zone's recovery rate becomes asymptotic, then it can be shut down and a new zone opened. Further evaluation of the mass recovery rates of all the SVE wells is underway and the results will be used to determine the optimum operational zones, if needed, and ON/OFF cycling times. The results will be reported in the next routine SVE system OM&M report.

SECTION 4

Summary and Path Forward

The SVE system was evaluated from November 2016 through February 2017. The following summarize the overall findings of this effort:

- Installation of the two new SVE wells and operational adjustments/optimization have significantly increased mass removal rates from the SVE system, greater than 10 times larger than the prior operating period. Continued operation of the new SVE wells and optimized SVE blower system for the next year or two will result in a significant additional mass removal.
- Airflow rates from the old and new SVE wells remain small, generally ranging from 5 to 25 scfm per well, and indicate that removal of VOCs from this low-permeability geologic material is limited by permeability. As such, achieving the soil cleanup goals identified in the CMS may not be technically practicable.
- Continued SVE operation implementing the mechanical and operational changes described in this report will maximize SVE mass removal from the subsurface. OM&M will continue for the next year and its effectiveness reassessed or until groundwater cleanup goals are met.
- The soil cleanup goals included in the CMS should be re-evaluated with respect to other remedial objectives (i.e. the groundwater quality cleanup criteria and media-specific risk pathways) – and the practical limit of SVE system operations. Recent soil sampling results highlight the need for alternative cleanup levels.

Continued evaluation will be conducted and additional improvements may be made if practical to further refine SVE OM&M procedures and enhance source mass removal by the SVE system. Continued operation of the SVE system is logical as long as it can provide the source mass reduction that will ultimately lead to achievement of the sitewide corrective measure objectives.

SECTION 5

References

CARBTROL Corporation. 2001. *Activated Carbon Adsorption for Treatment of VOC Emissions*.

CH2M HILL, Inc. (CH2M). 2017. *Technical Memorandum, Pfizer Arecibo, Soil Boring Investigation and Vapor Extraction and Monitoring Well Installation, Arecibo, Puerto Rico*. January 7.

Environmental Resource Technologies (ERTEC). 2005. *Final Corrective Measure Study Summary Report, Pfizer Pharmaceuticals LLC, Arecibo, Puerto Rico*. September 30.

Environmental Resource Technologies (ERTEC). 2016. *SVE Pulsing Operations Progress Report No. 11*. February to May 2016. Corrective Measure Study, Pfizer Pharmaceuticals LLC, Arecibo, Puerto Rico. September 29.

Tables

Table 1. SVE Blower Test Results

Short-term SVE System Optimization Testing Project

Former Pfizer Facility, Arecibo, Puerto Rico

Date	Time	Valve Position	Vacuum		Carbon bp[1]	Inlet Temp.	Exit Temp.	Mfg. Gauge		Anemometer	
			(in. Hgg)	(in. wcg)	(in. wcg)	(°F)	(°F)	(iCFM)	(SCFM)	(FPM)	(SCFM)
11/22/16	11:15	Open	1.6	22	7	96	124	117	107	8936	179
	11:50	1/2 open	2.5	34	7	96	130	100	88	7528	149
	11:56	1/4 open	3.8	52	7	96	134	80	67	6060	119
	12:03	1/8 open	3.9	53	7	96	140	0	0	5990	117
11/29/16	9:45	Open	1.8	24	7	NC	129	NC	NC	8032	159
	10:05	1/2 open	3	41	7	NC	148	NC	NC	6473	124
	11:05	1/4 open	3.9	53	7	NC	164	NC	NC	5662	106
	11:15	1/8 open	3.9	53	7	NC	165	NC	NC	5706	107

°F = degrees Fahrenheit

FPM = feet per minute

iCFM = inlet cubic feet per minute

in. Hgg = inches of mercury (gauge pressure)

in. wcg = inches of water column (gauge pressure)

Mfg. = manufacturer provided equipment

NC = not collected

SCFM = standard cubic feet per minute

bp[1] = one back pressure readings collected during additional testing

Table 2. Subsurface Pressure Distribution - Radius of Influence Test Results

Short-term SVE System Optimization Testing Project

Former Pfizer Facility, Arecibo, Puerto Rico

Purpose: To estimate radius of influence for soil vapor extraction around a single recovery well.

Assumptions

(1) Angular distance between SVE and VMP screened intervals.

(2) Homogeneous/Isotropic soil column.

(3) Subsurface pressure distributed radially about the SVE well.

Vacuum Event 11/30/16:

Observ. Wells	VMW-1	SVE-1	VMW-2	VMW-3C	VMW-4	SVE-2	SVE-3
Distance (ft)	0	15	15	40	40	44	49
Vacuum (in. wcg)	31	0	0	0	0	6	0

Observ. Wells	VMW-2	SVE-1	VMW-1	VMW-3C	SVE-3	VMW-4	SVE-2
Distance (ft)	0	15	15	20	33	61	63
Vacuum (in. wcg)	31	0	0	0	0	--	20

Observ. Wells	VMW-3C	SVE-1	VMW-2	SVE-3	VMW-1	SVE-2	VMW-4
Distance (ft)	0	17	20	23	40	87	86
Vacuum (in. wcg)	31	0	0	0	0	18	--

Observ. Wells	SVE-1	SVE-3	VMW-1	VMW-3C	VMW-2	SVE-2	VMW-4C
Distance (ft)	0	10	15	17	18	36	37
Vacuum (in. wcg)	31	0	0	0	0	22	0

Observ. Wells	SVE-2	VMW-4	SVE-1	VMW-1	VMW-2	VMW-3C	SVE-3
Distance (ft)	0	12	36	44	63	87	90
Vacuum (in. wcg)	31	0	0	0	0	0	0

Observ. Wells	SVE-3	SVE-1	VMW-3C	VMW-2	VMW-1	SVE-2	VMW-4
Distance (ft)	0	10	23	33	49	90	91
Vacuum (in. wcg)	31	0	0	0	0	26	0

Vacuum Event 12/01/16:

Observ. Wells	VMW-1	SVE-1	VMW-2	VMW-3C	VMW-4	SVE-2	SVE-3
Distance (ft)	0	15	15	40	40	43.7	49
Vacuum (in. wcg)	50	5.3	0	0	0	17	0

Observ. Wells	SVE-3	SVE-1	VMW-3C	VMW-2	VMW-1	SVE-2	VMW-4
Distance (ft)	0	9.5	23	33	49	90	91
Vacuum (in. wcg)	50	0.7	0	0	0	22	0

Vacuum Event 12/02/16:

Observ. Wells	SVE-2+3	SVE-1	VMW-3C	VMW-2	VMW-1	VMW-4	--
Distance (ft)	0	10	23	33	44	91	--
Vacuum (in. wcg)	42.5	0.9	20.3	0	11.4	0	--

Vacuum Event 1/03/17:

Observ. Wells	SVE-2+3	SVE-1	VMW-3C	VMW-2	VMW-1	VMW-4	--
Distance (ft)	0	10	23	33	44	91	--
Vacuum (in. wcg)	61.0	0	0.7	1.1	0.6	1.0	--

Table 3. Blower and SVE Well Operating Conditions and Mass Removal Calculations

Short-term SVE System Optimization Testing Project

Former Pfizer Facility, Arecibo, Puerto Rico

Well ID.	Date	Exit Temp.	Vacuum	Vacuum and Flow			VOCs PID	VOCs Equiv.	VOCs Lab	Correlation	Mass	*Opn Time*	*Cum. Mass*
		(°F)	(in. Hgg)	(in. wcg)	(FPM)	(SCFM)	(ppmV)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(lbs/day)	*(hrs)*	*Remov (lbs)*
Blower Outlet	12/01/16	140	4.0	54	4,976	97	0	0	NC	*0*	*0*	0	0
	12/02/16	144	3.5	48	5,241	101	0	0	0.7	*0*	0	*28*	*0*
	12/02/16	146	3.8	52	4,929	95	0	0	3.1	*0*	0.0	*1.5*	*0*
	12/06/16	148	4.1	56	4,710	90	0	0	NC	*0*	*0*	*93*	*0*
	12/09/16	150	4.1	56	4,739	91	0	0	46	*0*	0.4	*74*	*1*
	12/14/16	150	4.3	58	4,953	95	0	0	NC	*0*	*0*	*118*	*2*
	12/20/16	158	5.0	68	3,896	74	0.3	2	NC	*799*	*5*	*144*	*17*
	12/27/16	158	4.9	66	4,202	79	0	0	NC	*0*	*0*	*168*	*36*
	01/03/17	160	5.2	70	3,595	68	0	0	NC	*0*	*0*	*168*	*36*
	01/11/17	154	5.2	70	3,691	70	0	0	64	*0*	0.4	*194*	*38*
	01/17/17	158	6.0	70	3,546	67	0.7	4	NC	*1,865*	*11.2*	*143*	*72*
	02/13/17	154	6.2	68	3,905	74	0.2	1	103	*533*	0.7	*648*	*233*
	02/13/17	160	6.3	70	3,702	70	0	0	187	*0*	1	*2.3*	*233*
SVE-1	12/01/16	*85*	3.7	50	371	8	30.2	181	NC	*80,473*	*57*	0	0
	12/01/16	*85*	3.7	50	371	7	34.5	207	NC	*91,931*	*58*	*0.5*	*1*
	12/02/16	*85*	2.3	31	256	5	30.1	180	NC	*80,207*	*36*	*24*	*48*
	12/02/16	*85*	2.5	34	310	6	25.2	151	233,200	*67,150*	128	*1.5*	*53*
	02/13/17	*85*	4.3	58	350	6	26.4	158	41,039	*70,347*	24	0	*53*
SVE-2	12/01/16	*85*	3.6	49	475	9	46.7	280	NC	*124,440*	*100*	0	0
	12/02/16	*85*	2.5	34	374	7	7.9	47	5,550	*21,051*	3.7	*27*	*58*
	12/02/16	*85*	3.3	45	471	9	35.0	210	1,114	*93,264*	0.9	*2.5*	*58*
	12/06/16	*85*	3.9	53	689	13	23.4	140	NC	*62,353*	*72*	*92*	*198*
	12/09/16	*85*	3.8	52	387	7	4.2	25	4,363	*11,192*	2.8	*75*	*314*
	12/14/16	*85*	4.0	54	340	6	5.9	35	NC	*15,722*	*8.9*	*118*	*343*
	12/20/16	*85*	4.2	57	860	16	7.5	45	NC	*19,985*	*28*	*144*	*455*
	12/27/16	*85*	4.2	57	545	10	7.4	44	NC	*19,719*	*18*	*168*	*617*
	01/03/17	*85*	4.5	61	589	11	15.7	94	NC	*41,835*	*40*	*168*	*820*
	01/11/17	*85*	4.4	60	626	11	3.4	20	10,250	*9,060*	11	*195*	*1,026*
	01/17/17	*85*	4.5	61	485	9	4.6	28	NC	*12,258*	*9.7*	*142*	*1,086*
	02/13/17	*85*	4.1	55	714	13	2.9	17	1,876	*7,728*	2.2	*647*	*1,248*
SVE-3	12/01/16	*85*	3.6	49	310	6	31.4	188	NC	*83,671*	*44*	0	0
	12/02/16	*85*	2.3	31	177	4	10.8	65	32,600	*28,778*	10	*26*	*30*
	12/02/16	*85*	3.3	44	504	10	15.7	94	34,700	*41,835*	30	*2.2*	*32*
	12/06/16	*85*	3.9	53	449	8	13.0	78	NC	*34,641*	*26*	*92*	*139*
	12/09/16	*85*	3.8	52	710	13	6.5	39	5,012	*17,320*	6.0	*75*	*189*
	12/14/16	*85*	3.9	53	721	13	0.9	5	NC	*2,398*	*2.9*	*118*	*211*
	12/20/16	*85*	4.2	57	368	7	4.4	26	NC	*11,725*	*7.1*	*144*	*241*
	12/27/16	*85*	4.2	57	291	5	2.3	14	NC	*6,129*	*3.0*	*168*	*276*
	01/03/17	*85*	4.5	61	350	6	26.1	156	NC	*69,548*	*40*	*168*	*426*
	01/11/17	*85*	4.4	60	323	6	13.6	81	67,490	*36,240*	36	*195*	*733*
	01/17/17	*85*	4.5	61	264	5	9.2	55	NC	*24,515*	*11*	*142*	*870*
	02/13/17	*85*	4.1	55	401	7	7.0	42	36,241	*18,653*	24	*647*	*1,339*

Table 3. Blower and SVE Well Operating Conditions and Mass Removal Calculations

Short-term SVE System Optimization Testing Project

Former Pfizer Facility, Arecibo, Puerto Rico

Well ID.	Date	Exit Temp.	Vacuum	Vacuum and Flow			VOCs PID	VOCs Equiv.	VOCs Lab	Correlation	Mass	*Opn Time*	*Cum. Mass*
		(^oF)	(in. Hgg)	(in. wcg)	(FPM)	(SCFM)	(ppmV)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(lbs/day)	*(hrs)*	*Remov (lbs)*
VMW-1	12/01/16	*85*	*3.5*	48	637	12	8.7	52	NC	*23,183*	*25*	0	0
	12/01/16	*85*	*3.5*	48	569	11	14.6	87	NC	*38,904*	*38*	*0.5*	*1*
	12/02/16	*85*	2.3	31	307	6	8.2	49	NC	*21,850*	*12*	*23*	*24*
	12/02/16	*85*	2.5	34	555	11	11.4	68	17,085	*30,377*	17	*2.3*	*26*
	02/13/17	*85*	4.3	58	648	12	4.2	25	11,575	*11,192*	12	0	*26*
VMW-2	12/01/16	*85*	*3.5*	48	290	5	8.3	50	NC	*22,117*	*11*	0	0
	12/01/16	*85*	*3.5*	48	374	7	10.5	63	NC	*27,979*	*18*	*0.5*	*0*
	12/02/16	*85*	2.3	31	263	5	10.1	61	NC	*26,913*	*13*	*22*	*14*
	12/02/16	*85*	2.5	34	255	5	7.4	44	14,170	*19,719*	6.4	*2.4*	*15*
VMW-3C	12/01/16	*85*	*3.5*	48	1,011	19	3.8	23	NC	*10,126*	*17*	0	0
	12/01/16	*85*	*3.5*	48	1,003	19	2.4	14	NC	*6,395*	*11*	*0.5*	*0*
	12/02/16	*85*	2.4	32	814	16	3.7	22	NC	*9,859*	*14*	*21*	*11*
	12/02/16	*85*	2.5	34	842	17	0.5	3	3,370	*1,332*	5.0	*2.5*	*12*

CCl_4 = carbon tetrachloride

in. Hgg = inches of mercury (gauge pressure)

lbs = pounds

NC = not collected

ppmV = parts per million (by volume)

SCFM = standard cubic feet per minute

Vac. = vacuum

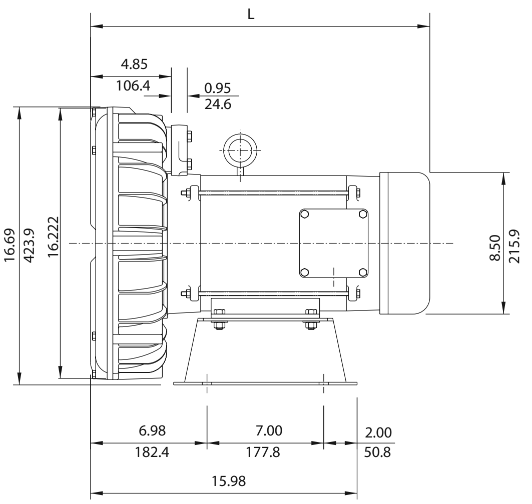
VOCs = volatile organic compounds

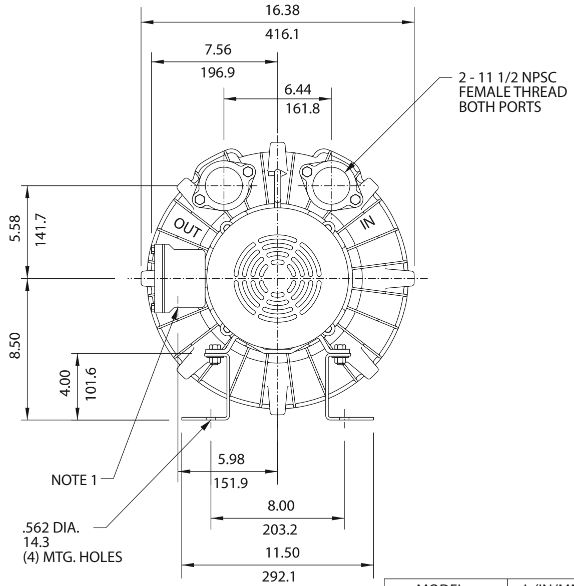
Attachment 1
Manufacturer’s Specifications Sheet for the Ametek Rotron EN6F72L

EN 6 & CP 6

ROTRON®

5.0 HP Sealed Regenerative w/Explosion-Proof Motor





NOTES
1 TERMINAL BOX CONNECTOR HOLE 3/4" NPT FEMALE THREAD POSITIONED AT 12 O'CLOCK.
2 DRAWING NOT TO SCALE, CONTACT FACTORY FOR SCALE CAD DRAWING.
3 CONTACT FACTORY FOR BLOWER MODEL LENGTHS NOT SHOWN.

MODEL	L (IN/MM)
EN6F72L	16.13/409.7
EN6F5L	20.84/529.2

		Part/Model Number				
		EN6F5L	EN6F72L	EN6F86L	CP6FW5LR	CP6FW72LR
Specification	Units	038361	038180	038438	TBD	038978
Motor Enclosure - Shaft Mtl.	-	Explosion-proof-CS	Explosion-proof-CS	Explosion-proof-CS	Chem XP-SS	Chem XP-SS
Horsepower	-	5.0	5.0	5.0	5.0	5.0
Phase - Frequency	-	Single-60 hz	Three-60 hz	Three-60 hz	Single-60 hz	Three-60 hz
Voltage	AC	230	230/460	575	230	230/460
Motor Nameplate Amps	Amps (A)	19.5	14/7	5.7	19.5	14/7
Max. Blower Amps	Amps (A)	23	14/7	6.3	23	14/7
Inrush Amps	Amps (A)	175	152/76	38	175	152/76
Starter Size	-	2	1/0	0	2	1/0
Service Factor	-	1.0	1.0	1.0	1.0	1.0
Thermal Protection	-	Class B - Pilot Duty	Class B - Pilot Duty	Class B - Pilot Duty	Class B - Pilot Duty	Class B - Pilot Duty
XP Motor Class - Group	-	I-D, II-F&G	I-D, II-F&G	I-D, II-F&G	I-D, II-F&G	I-D, II-F&G
Shipping Weight	Lbs	232	160	160	232	160
	Kg	105.2	72.6	72.6	105.2	72.6

Voltage - Rotron motors are designed to handle a broad range of world voltages and power supply variations. Our dual voltage 3 phase motors are factory tested and certified to operate on both: **208-230/415-460 VAC-3 ph-60 Hz** and **190-208/380-415 VAC-3 ph-50 Hz**. Our dual voltage 1 phase motors are factory tested and certified to operate on both: **104-115/208-230 VAC-1 ph-60 Hz** and **100-110/200-220 VAC-1 ph-50 Hz**. All voltages above can handle a ±10% voltage fluctuation. Special wound motors can be ordered for voltages outside our certified range.

Operating Temperatures - Maximum operating temperature: Motor winding temperature (winding rise plus ambient) should not exceed 140°C for Class F rated motors or 120°C for Class B rated motors. Blower outlet air temperature should not exceed 140°C (air temperature rise plus inlet temperature). Performance curve maximum pressure and suction points are based on a 40°C inlet and ambient temperature. Consult factory for inlet or ambient temperatures above 40°C.

Maximum Blower Amps - Corresponds to the performance point at which the motor or blower temperature rise with a 40°C inlet and/or ambient temperature reaches the maximum operating temperature.

XP Motor Class - Group - See Explosive Atmosphere Classification Chart in Section I

AMETEK TECHNICAL & INDUSTRIAL PRODUCTS
75 North Street, Saugerties, NY 12477
USA: +1 215.256.6601 - Europe: +420 494 943 062 - Asia: (86-21) 57631258
Customer Service Fax: +1 215.256.1338
www.ametektip.com

AMETEK TECHNICAL & INDUSTRIAL PRODUCTS

Environmental / Chemical Processing Blowers

EN 6 & CP 6

ROTRON®

5.0 HP Sealed Regenerative w/Explosion-Proof Motor

FEATURES
- Manufactured in the USA - ISO 9001 and NAFTA compliant
- Maximum flow: 210 SCFM
- Maximum pressure: 110 IWG
- Maximum vacuum: 85 IWG
- Standard motor: 5.0 HP, explosion-proof
- Cast aluminum blower housing, impeller , cover & manifold; cast iron flanges (threaded); teflon® lip seal
- UL & CSA approved motor with permanently sealed ball bearings for explosive gas atmospheres Class I Group D minimum
- Sealed blower assembly
- Quiet operation within OSHA standards

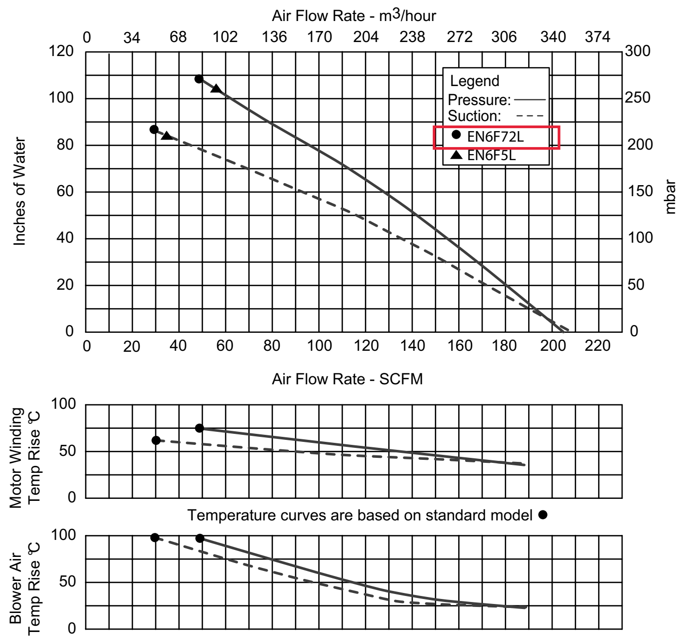
MOTOR OPTIONS
- International voltage & frequency (Hz)
- Chemical duty, high efficiency, inverter duty or industry-specific designs
- Various horsepowers for application-specific needs

BLOWER OPTIONS
- Corrosion resistant surface treatments & sealing options
- Remote drive (motorless) models
- Slip-on or face flanges for application-specific needs

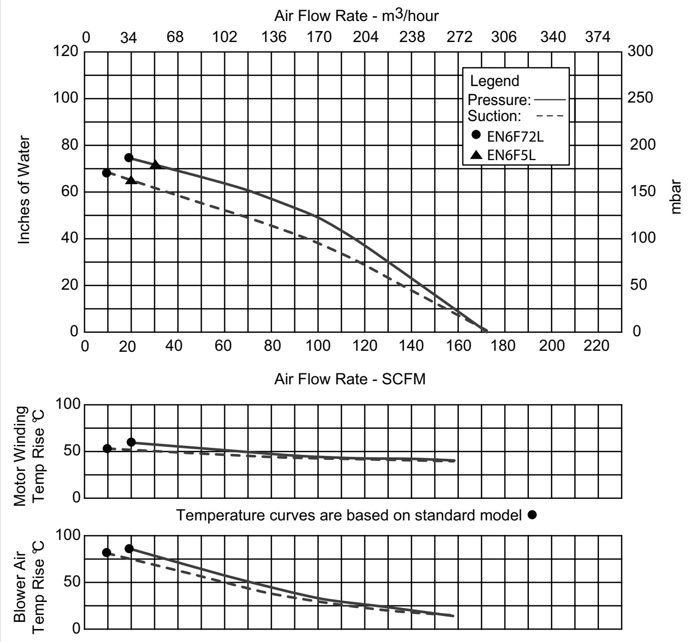
ACCESSORIES
- Flowmeters reading in SCFM
- Filters & moisture separators
- Pressure gauges, vacuum gauges, & relief valves
- Switches - air flow, pressure, vacuum, or temperature
- External mufflers for additional silencing
- Air knives (used on blow-off applications)
- Variable frequency drive package

Blower Performance at Standard Conditions

60 Hz



50 Hz



Attachment 2
Activated Carbon Adsorption for Treatment of VOC Emissions (CARBTROL Corporation, 2001)

ACTIVATED CARBON ADSORPTION FOR TREATMENT OF VOC EMISSIONS

Presented at the 13th Annual EnviroExpo, Boston Massachusetts—May 2001

Austin Shepherd, P.E., C.I.H.
Vice President, Technical Director, CARBTROL Corporation
e-mail: a.shepherd@carbtrol.com

A review of the characteristics of activated carbon and its applicability to emission control of VOC's. Design and costs of carbon systems are also discussed.

INTRODUCTION

The principal use of vapor phase activated carbon in the environmental field is for the removal of volatile organic compounds such as hydrocarbons, solvents, toxic gases and organic based odors. In addition, chemically impregnated activated carbons can be used to control certain inorganic pollutants such as hydrogen sulfide, mercury, or radon.

When properly applied, the adsorption process will remove pollutants for which it is designed, to virtually non-detectable levels. In fact one of the first large- scale uses of activated carbon was in military gas masks where complete contaminant removal is essential. Carbon adsorption is equally effective on single component emissions as well as complex mixtures of pollutants.

In the industrial area, the most common applications of activated carbon are for process off-gases, tank vent emissions, work area air purification, and odor control, either within the plant or related to plant exhausts. Additionally, activated carbon is used in the hazardous waste remediation area to treat off-gases from air strippers and from soil vapor extraction remediation projects.

EVALUATION OF ALTERNATIVE TREATMENT PROCESSES	LOW VOC LEVELS	HIGH VOC LEVELS	CONTINUOS LOADS	INTERMITTENT LOADS	HALOGENATED ORGANICS	TEMP>150F	TEMP<150F	HIGH FLOWS	LOW FLOWS	HIGH HUMIDITY	INORGANIC PARTICLES
ACTIVATED CARBON	•		•	•	•		•	•	•		
THERMALOXIDATION		•	•			•			•	•	
SCRUBBERS	•	•	•			•	•	•	•		
PARTICULATE FILTERS			•	•			•			•	•
CATALYTIC OXIDATION		•	•			•			•	•	

TABLE I

APPLICATION CONSIDERATIONS

One of the major issues that must first be addressed when evaluating a specific environmental VOC problem is what treatment technology to consider. For a given situation there are likely a number of treatment alternatives that appear to have some utility.

The first step in this evaluation is to effectively characterize the application. You will need to know at least the following information:

Flow Rate - Continuos vs intermittent
Contaminants Present – individual contaminants, concentration and variability
Temperature - Average and maximum
Falamibility - Upper and lower explosive limits

Once you have characterized your problem, each technology can be considered for its ability to deal with the conditions identified. As an example, *Table I* lists some of the more common technologies used to control industrial vapor phase pollutants, and the conditions under which they might be most favorably applied. I can't stress enough the importance of this review, as this is where most technical solutions fail. If you solve the wrong problem or pick a technical solution that does not respond to all the variables of your application, poor performance will likely result.

HOW IT WORKS

In the adsorption process, molecules of a contaminated gas are attracted to and accumulate on the surface of the activated carbon. Carbon is a commonly used adsorbent due to its very large surface area. It can be made from a variety of base materials including coal, wood and coconut shells, and is manufactured or activated in a high temperature controlled oxidation process. A pound of highly activated carbon has a surface area approaching 140 acres.

CROSS SECTION OF CARBON

This *Figure I* presents an artist's rendition of the cross section of an activated carbon particle. Note that almost all of the surface area available for adsorption is associated with its internal pore structure. Also note the relative change in pore diameters, going from very large at the granule surface boundary, to much smaller within the particle interior. Balancing of the large and small pore volumes during the activation process is what makes individual activated carbons perform differently. Molecules of a contaminant tend to adsorb most strongly in areas where the pore diameter of the adsorbent is close to the molecular diameter of the compound.

While most organic compounds will adsorb on activated carbon to some degree, the adsorption process is most effective on higher molecular weight and high boiling point compounds.

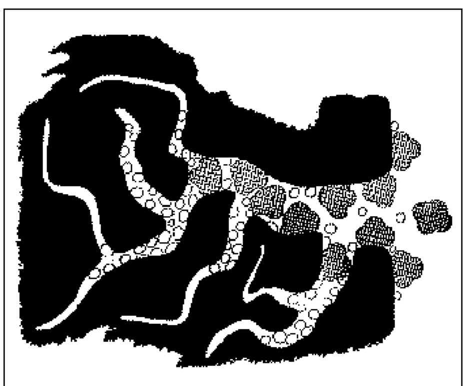


FIGURE I

LIST OF ORGANIC COMPOUNDS

RELATIVE ADSORBTION RATE

		MOLECULAR WEIGHT	BOILING POINT	CARBON CAPACITY %
WEAKER ---------------- STRONGER	NITROBENZENE	123	211 C	51
	TETRACHLOROETHANE	166	147 C	40
	TETRACHLOROETHYLENE	165	121 C	35
	STYRENE	104	145 C	25
	XYLENE	106	138 C	21
	NAPATHYLENE	128	217 C	20
	TOLUNE	92	111 C	20
	BENZENE	78	80 C	12
	MTBE	88	55 C	12
	HEXANE	86	68 C	7
	ETHLY ACRILATE	100	57 C	5
	DIDHLOROETHANE	99	99 C	7
	METHYL ETHYLKETONE	72	80 C	4
	METHYLENE CHLORIDE	84	40 C	2
	ACRILONITRILE	53	74 C	2
	ACETONE	58	56 C	0.8
	VINYLCHLORIDE	62	neg 14 C	0.7
	CHLOROETHANE	64	12 C	0.5
	BROMOTRI FLOROMETHANE	149	neg 58 C	0.13
	METHANE	16	neg 161 C	0.0003

TABLEII

Compounds having a molecular weight over 50 and a boiling point greater than 50 degrees centigrade are good candidates for adsorption. *TABLE II* presents a representative list of organic compounds and their relative adsorption strength. Organic contaminants are often classified as weakly, moderately, or strongly adsorbed. You will note that a compound such as nitrobenzene having a molecular weight of 123 and a boiling point of 211 C is characterized as a very strong adsorber. On the other hand a compound such as methane which has a molecular weight of 16 and a boiling point of –161 C is a very weakly adsorbed compound. In fact, at this capacity, for all practical purposes, methane removal with activated carbon would not be cost effective.

ABSORPTION CAPACITY

Physical adsorption is dependant on the characteristics of the contaminant to be adsorbed, the temperature of the gas stream to be processed, and the concentration of the contaminant in the gas stream. The adsorption capacity for a particular contaminant represents the amount of the contaminant that can be adsorbed on a unit weight of activated carbon consumed at the conditions present in the application. Typical adsorption capacities for moderately adsorbed compounds range from 5 to 30 percent of the weight of the carbon.

TRICHLOROETHYLENE ISOTHERM

The adsorption isotherm plot shows the influence of concentration on adsorption capacity. *Figure II* presents an adsorption isotherm used to predict adsorption capacity for trichloroethylene. Note how the adsorption capacity varies from 20 to 65 percent over the concentration range of 10 to 10000 ppm in the gas stream.

A series of isotherms at differing temperatures shows the influence of temperature on adsorption capacity. In Figure III you can see the effect of temperature on the same trichloroethylene compound. At 100ppm the capacity of activated carbon for trichloroethylene varies from 17 to 40 percent as the temperature changes from 140 to 32 degrees F.

Fortunately, most carbon suppliers have developed isotherms for a range of environmental contaminants. At Carbtrol we have built a computerized database of adsorption isotherms so that we can easily model most environmental applications. By supplying to us the gas flow rate, the contaminant concentration and the temperature of the gas stream, a carbon usage prediction can be made.

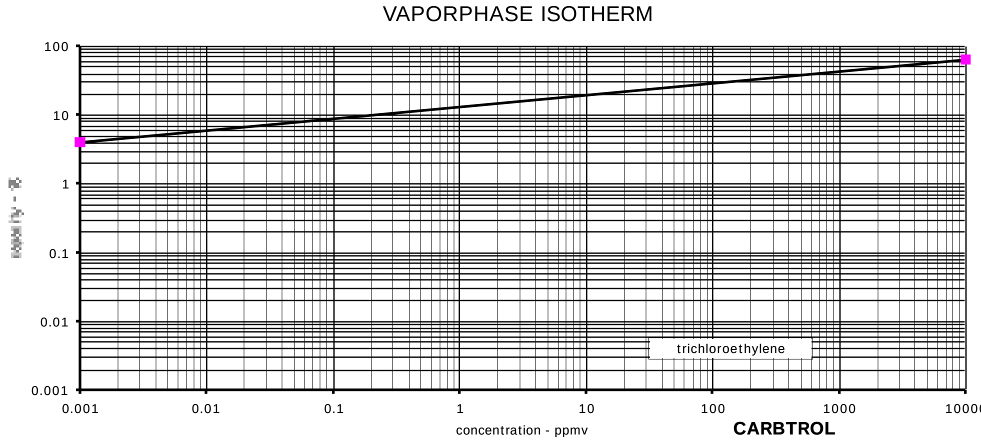


FIGURE II

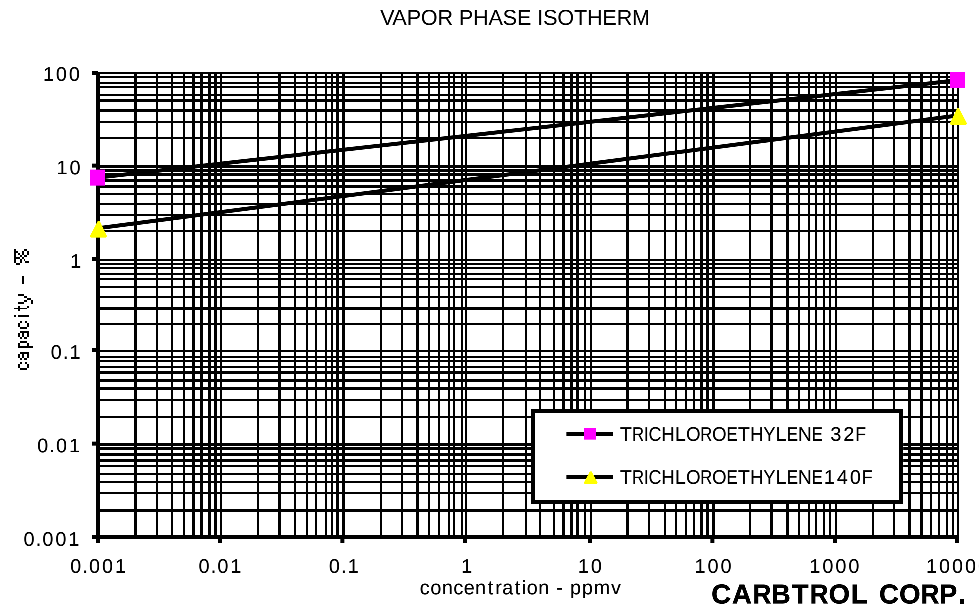
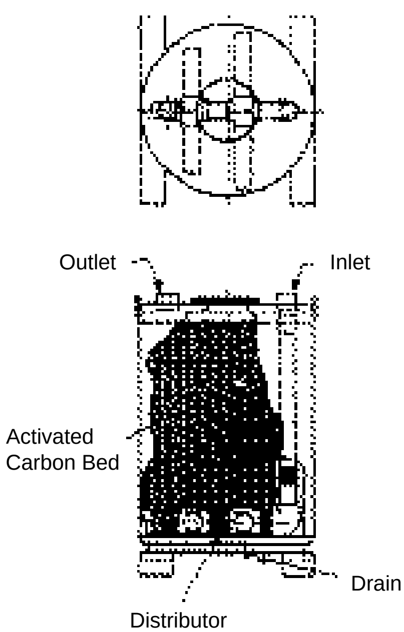


FIGURE III

DESIGN CONSIDERATIONS



CARBTROL G-4 ADSORBER

FIGURE IV

Activated carbons used in the air pollution control field are normally supplied in a granular form with a particle size ranging from 1 to 5 millimeters. In the granular form activated carbon can easily be packed into a containment device through which a contaminated gas stream can be processed for purification.

Figure IV shows the cross section of a typical fixed bed vapor phase adsorber. An adsorption system in its simplest form is made of a containment device (drum or vessel), distribution and collection devices to effect proper circulation of the gas stream through the activated carbon bed, and a means for moving the gas stream through the bed (such as a fan, a blower, or pressurized gas displacement). Packed activated carbon beds can be conveniently config-